DESCRIPTION

METHOD AND SYSTEM OF DRYING MATERIALS AND METHOD OF MANUFACTURING CIRCUIT BOARDS USING THE SAME

FIELD OF THE INVENTION

The present invention relates to a method and system of drying materials and a method of manufacturing circuit boards using the same.

BACKGROUND OF THE INVENTION

With recent downsizing and high density of electronic equipment, a double-sided or multi-layered circuit board is employed more frequently than a conventional single-sided board, as a circuit board on which electronic components are mounted, and a high density circuit board allowing a larger number of circuits to be integrated in a circuit board is developed.

For the high density circuit board, instead of drilling of holes (through holes) in the board, which is conventionally operated, employment of laser machining capable of faster and more fine machining is developed (Y. Yamanaka et al. "Excimer Laser Processing In The Microelectronics Fields", for example). Also proposed is a circuit board in which layers are connected using fine holes made by laser and such connection means as conductive paste (shown in Japanese Patent Application Non-examined Publication No. H06-268345, for example).

In the technique of making fine holes and connecting layers using conductive paste, a few foreign substances may cause contact failure.

In this technique, the substrate material is drilled together with a film bonded thereto and the film is used as a mask for filling the conductive paste into the fine holes. Therefore, all the substrate material including the film must be kept clean.

However, both drilling and laser machining produce a large amount of dust and debris from the cutting process, and this dust and debris may adhere to the board material and close the holes for electrical connection. In addition, it is also possible that a little dust in air may close the fine holes. To solve this problem, the board material is cleaned before the conductive paste is filled in the holes. However, because complete cleaning of the holes by a dry cleaning method is very difficult, such new wet cleaning methods as ultrasonic cleaning are employed. These methods require drying after cleaning, in order to remove the moisture absorbed from the periphery of the machined holes or the outer ends of the board material.

As shown in Fig. 4 (a), mask films 2a and 2b are bonded to substrate material 1. Provided at an end of substrate material 1 are peel off leading parts 3a and 3b for stripping mask films 2a and 2b after the conductive paste is filled. The leading parts 3a and 3b are made by stripping a part of each of mask films 2a and 2b.

Because of such a structure, when sheets of substrate material 1 are stacked one on top of another and dried by heating using a conventional hot air convection method as shown in Fig. 4 (b), B-stage epoxy resin in the board material melts and stripping leading parts 43a and 43b and substrate material 1 melt together again, as shown in Fig. 4 (c). Therefore, it is difficult to treat and sufficiently dry a large number of sheets at a time.

A small number of sheets could be treated with a vacuum dryer. However, it takes long time to dry a large number of sheets because sufficient latent heat cannot be given to the material under vacuum and thus energy sufficient to remove the moisture cannot be added.

In improving reliability of connection in circuit boards, wet cleaning is more effective than dry cleaning. However, insufficient drying after cleaning would significantly affect the reliability of connection and insulation.

For this reason, moisture must be removed completely. However, the conventional method is not efficient and may possess problems e.g. causing more damage to the board material.

The present invention is directed to realize a board material having high-quality fine holes and to provide a method and a system of manufacturing highly reliable circuit boards at low cost.

DISCLOSURE OF THE INVENTION

In order to address the above-mentioned problems, a method of manufacturing circuit boards in accordance with the present invention includes a bonding step of bonding a film-like material to at least one side of a board material to form a substrate material having a film(s). The method of manufacturing circuit boards also includes: a hole-forming step of drilling a through or a blind hole in the board material made of a plurality of materials; and a step of forming a connection means in the through or blind hole for mutually connecting circuits formed on or in the circuit board. The hole-forming step includes: a step of irradiating the board material with laser to form a through or blind hole shape; and a step of cleaning to remove foreign substances that have attached to the surface of the board material and the inner wall of the through or blind hole in the previous step. The method can provide a clean and highly reliable board material by efficiently drying the moisture absorbed by the board material, without damaging the board material, after the removal of water drops that have adhered to the surface of the board material in a cleaning process.

Therefore, in accordance with the present invention, high-quality drilling can be achieved without losing high speed of the laser machining, and a highly reliable circuit board can be provided at low cost.

BRIEF DESCRIPTION OF THE DRAWINGS

Figs. 1(a) - 1(h) are cross sectional views showing a process of a method of manufacturing a circuit board in accordance with an exemplary embodiment of the present invention.

Fig. 2 is a schematic diagram of a circuit board manufacturing system in accordance with the embodiment.

Fig. 3 is a graph showing a profile of pressures in a vacuum chamber for use with a material drying method in accordance with the present invention.

Figs. 4(a) - 4(c) are cross sectional views showing a process of a conventional method of manufacturing a circuit board.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

An exemplary embodiment of the present invention is hereinafter described with reference to Figs. 1 to 3.

Figs. 1(a) to 1(h) show cross sectional views of a process of a method of manufacturing a multi-layered circuit board in accordance with the present embodiment.

In Figs. 1(a) - 1(h), reference numeral 1 shows a substrate material that is a square plate of 250 mm on each side and approx. 150 μm thick, as an insulating substrate. Used as the substrate material is a resin impregnated substrate made of a composite material in which an non-woven fabric made of an aromatic polyamide fiber (hereinafter referred to as "aramid fiber") is impregnated with a thermosetting epoxy resin (hereinafter referred to as "epoxy resin"), for example. The epoxy resin in accordance with the present embodiment is a so-called "B stage" epoxy resin that contains an uncured portion.

Reference numerals 2a and 2b show strippable resin films for masking films, each of which is approx. 20 μm thick. On their surfaces

that are to adhere to substrate material 1, thermosetting epoxy resin layers (not shown) of approx. 1 μm thick each are applied. Polyethylene terephthalate (hereinafter referred to as "PET sheet") is used as the strippable resin film, for example. Board material 1a is made by bonding PET sheets 2a and 2b to substrate material 1.

At one end of board material 1a, peel off leading parts 3a and 3b are previously provided between substrate material 1 and PET sheets 2a and 2b so as to peel off PET sheets 2a and 2b afterwards. The peel off leading parts 3a and 3b are made by stripping off a part of each PET sheet from substrate material 1.

Next, as shown in Fig. 1 (b), substrate 1a is irradiated with laser light 4 to form through hole 5. At this time, part of the thermosetting epoxy resin and aramid fiber in board material 1a is sublimed by heat, and scatters to its surroundings. However, the thermosetting epoxy resin and aramid fiber that have not been sublimed remain on the wall surface of the hole, as hard and brittle altered portions 6.

Because the aramid fiber is more heat-resistant than the thermosetting epoxy resin and thus has a lower laser-machining rate, the aramid fiber is likely to remain without subliming. Therefore, the inner wall of the hole has rough surfaces as shown in the drawing.

On the other hand, part of the thermosetting epoxy resin or aramid fiber that has scattered to its surroundings adheres to the surface of board material 1a or the inside of through hole 5 as cutting dust 7.

Next, as shown in Fig. 1(c), board material 1a is placed near ultrasonic vibrator 9 and vibrated in, for example, water in the ultrasonic cleaning vessel 8. The acoustic energy radiated from ultrasonic vibrator 9 vibrates board material 1a and altered parts 6 and cutting dusts 7 fall out or are peeled off from board material 1a. As a result, board material 1b having a proper hole shape as shown in Fig. 1 (d) is obtained. Additionally, water drops adhering to the surface

of board material 1b are removed by blowing air therethrough or the like.

However, at the end of the air blowing process, in through hole 5 and peel off leading parts 3a and 3b of board material 1b, some moisture absorbed therein may still remain.

Next, as shown in Fig. 1 (e), two sets 10 of 180 sheets of board material 1b stacked are prepared and placed in vacuum chamber 11, and board material 1b is dried.

Fig. 2 shows a schematic diagram of a dryer in accordance with the present invention. Pre-heater 31 are provided around vacuum chamber 11, and a vacuum system comprising a vacuum pump 32, and foreign substance removing filter 35 for protecting vacuum pump 32 is connected to the chamber.

In addition, the dryer has hot air supplier 33 comprising hot air generator 34, foreign substance removing filter 35, and air dryer 36 for pressurizing the chamber.

In one variation, control system 60, which is a programmable microcontroller based system, can be utilized to automatically control the operation of the pre-heater 31, the vacuum pump 32 and the hot air supplier 33.

Board material 1b placed in vacuum chamber 11 is evacuated and dried while being heated by radiation heat radiated from pre-heater 31.

In one variation, instead of using pre-heater 31, microwaves can be used for drying.

Next, an exemplary operation system of vacuum drying is described using Fig. 3.

(1) After placement of the board material, the vacuum pump is actuated to evacuate the chamber to a pressure of approx. 100 Pa.

(2) Next, the evacuation operation is stopped.

(3) Hot air supplier 33 supplies dry air at a temperature of approx. 60 °C that has been filtered through an air cleaner to vacuum chamber 11 and the chamber is pressurized to atmospheric pressure.

(4) After pressurizing, dry air is continuously supplied, and air in vacuum chamber 11 is circulated. Simultaneously evacuation using vacuum pump 32 makes air circulation efficient.

(5) Dry air is circulated for approx. one minute after the pressurization. Then the supply of dry air is stopped and the chamber is evacuated to a pressure of approx. 70 Pa.

(6) The above-described steps (2), (3), and (4) are repeated.

(7) After dry air is circulated for one minute after the pressurization, dry air supply is stopped and the chamber is evacuated to a pressure of approx. 40 Pa.

(8) Next, the evacuation operation is stopped.

(9) After hot air supplier 33 supplies dry air at a temperature of approx. 60 °C that has been filtered through the air cleaner to vacuum chamber 11 and the chamber is pressurized to atmospheric pressure, board material 1b is taken out of vacuum chamber 11.

It is noted that further repetition of these steps will enhance the degree of vacuum and dryness of the board material. To obtain a required dryness, the number of repetitions, ultimate pressure, temperature of dry air can be optimized according to the material.

An example of optimized conditions and the corresponding results are shown below:

First evacuation: degree of vacuum: 500 Pa → After reaching the ultimate pressure, dry air is introduced and the chamber is pressurized (at atmospheric pressure kept for one minute).

Second evacuation: degree of vacuum: 300 Pa → After reaching the ultimate pressure, dry air is introduced and the chamber is pressurized (at an atmospheric pressure kept for one minute).

Third evacuation: degree of vacuum: 150 Pa → After reaching the ultimate pressure, dry air is introduced and the chamber is pressurized (at an atmospheric pressure kept for one minute).

Fourth evacuation: degree of vacuum: 150 Pa → After reaching the ultimate pressure, dry air is introduced and the chamber is pressurized (at an atmospheric pressure kept for one minute).

The above four evacuating and pressurizing processes are then continually repeated until eighteen evacuations have been performed.

Then, the nineteenth evacuation: degree of vacuum: 150 Pa → After reaching the ultimate pressure, dry air is introduced and the chamber is pressurized (at an atmospheric pressure kept for one minute).

Twentieth evacuation: degree of vacuum: 150 Pa → After reaching the ultimate pressure, dry air is introduced and the chamber is pressurized (at an atmospheric pressure kept for one minute). → Completion

In the above processes: temperature of dry air: 60 °C

Total process time: approx. 40 minutes

Results of dryness:

		Change in substrate weight		
		Before cleaning	After cleaning	After drying in vacuum
Upper part of Pallet 1	No. 1	38.33	38.64 (+0.31)	38.28 (-0.05)
	No. 2	38.45	38.73 (+0.28)	38.39 (-0.06)

		Change in substrate weight		
		Before cleaning	After cleaning	After drying in vacuum
Middle part of Pallet 1	No. 1	38.46	38.75 (+0.29)	38.41 (-0.05)
	No. 2	38.54	38.84 (+0.30)	38.48 (-0.06)
Lower part of Pallet 1	No. 1	38.26	38.49 (+0.23)	38.16 (-0.10)
	No. 2	38.27	38.56 (+0.29)	38.17 (-0.10)
Upper part of Pallet 2	No. 1	38.37	38.66 (+0.29)	38.25 (-0.12)
	No. 2	38.43	38.75 (+0.28)	38.35 (-0.08)
Middle part of Pallet 2	No. 1	38.17	38.52 (+0.35)	38.14 (-0.03)
	No. 2	38.37	38.71 (+0.34)	38.29 (-0.08)
Lower part of Pallet 2	No. 1	38.01	38.31 (+0.30)	38.00 (-0.01)
	No. 2	38.17	38.49 (+0.32)	38.14 (-0.03)

Measuring samples were placed in each of the upper, middle, and lower parts of the right and left pallets in the chamber and the weight of the materials before cleaning, after cleaning, and after drying was measured. The results show that the weight after drying under vacuum is less than that of before cleaning and moisture has sufficiently been removed.

Next, as shown in Fig. 1 (f), conductive paste 14 is filled in through holes 5 using such means as printing. As through holes 5 have a proper shape, the inside of through holes 5 can completely be filled with conductive paste 14 without hindrance. After the filling, mask films made of PET sheets 2a and 2b are stripped off.

Next, as shown in Fig. 1 (g), board material 1b is sandwiched by metal foils 15 and heated and pressed using a hot press (not shown). This operation completely cures board material 1b that has been in the pre-preg state and electrically connects metal foils 15 bonded to the both sides of board material 1b together via conductive paste 14.

Next, metallic foils 15 are patterned to a desired pattern and a double-sided circuit board that has circuit patterns 16 as shown in Fig. 1 (h) is obtained.

The drying method in accordance with this embodiment can also be used for drying a double-sided circuit board that has been washed after the patterning.

In this embodiment, a double-sided circuit board is described. However, it is noted that the method can be applied to a multi-layered circuit board by repeating the steps in accordance with the present invention a plurality of times.

In the present invention, the case where conductive paste 14 is filled in through holes 5 in board material 1b is described. However, in the case where plated conductor is formed in through holes 5, the same effect can be obtained.

INDUSTRIAL APPLICABILITY

As described above, a method and a system of manufacturing a circuit board in accordance with the present invention comprise the following steps. A step of irradiating a board material with laser to form a through or blind shaped holes. A step of obtaining a desired

through or blind shaped holes by water cleaning and removing altered substances in the form of powder or blocks that have scattered from the board material and adhered during or after the laser irradiation step. The altered substances are formed on the surface of the board material and the inner wall of the through-holes or blind holes. Removing water drops that have attached to the surface of the board material in the cleaning step. Drying the board material by the gross to dry the moisture absorbed in the board material in the cleaning process, without causing thermal damage to the board material, by repeating evacuation and pressurization cycles while heating the board material. Thus, high-quality drilling can be achieved without losing quickness of laser machining, and highly reliable circuit boards can be obtained at low cost.